1907MNRAS..67..543B

On the "Owl" Nebula, Messier 97 = N.G.C. 3587. 1860.0. $\alpha = 11^h 6^m 40^s$. $\delta = +55^\circ 46'\cdot7$. By E. E. Barnard. (Plate 3.)

There has always been much interest attached to the great reflecting telescope of Lord Rosse. This giant instrument was used mostly in the study of the nebulæ, for which its great light-grasping power made it singularly useful. All the well-known nebulæ were studied with it, and drawings or sketches were made of many of them. There is little known as to the performance of the instrument on objects where definition was specially required. A comparison with the large modern refractors can only be had, therefore, through the agency of the nebulæ. Such a comparison must be crude at best from the difference in climate, observers, etc. Nevertheless, it would seem possible to form some idea of the power of the telescope in dealing with the nebulæ by a comparison of the drawings and descriptions with the present appearance of these objects as seen in the actual sky. To compare these drawings with photographs of the nebulæ would be very unfair, because of the extraordinary power of the sensitive plate compared with that of the eye when dealing with such objects.

A visual comparison of this kind would be well worth while, and might lead to important information concerning probable changes in the nebulæ, though there seems to be but little hope of anything in this direction except through the aid of photography at very long intervals of time.

The relative amount of light collected by the 40-inch refractor of the Yerkes Observatory and the 6-foot Rosse reflector would be 1 : 32 for a point source. If the relative effectiveness were the same, the 6-foot should have shown an object 32 times fainter than could be seen with the 40-inch telescope. Inasmuch as the great speculum was of metal, there must have been a serious loss of light to begin with. The power of the instrument must also have varied greatly according to the condition of the surface of the speculum, for Lord Rosse stated that it was subject to considerable tarnish because of the necessary amount of copper in the material.

I have examined, both with the 36-inch of the Lick Observatory and the 40-inch here, a large number of the nebulæ—especially of the planetary nebulæ—which were drawn by Lord Rosse and his assistants. From their observations, I believe, on the whole, that the 40-inch telescope will show anything that could have been seen with the great reflector, even where light alone is concerned. True, there are some details of the nebulæ in the Rosse drawings that are not visible in the 40-inch. At the same time there are others that the great reflector failed to see which are visible in the 40-inch. There is little to be said on this point, therefore, without prejudice.

Very often the Rosse drawings show fringes around the planetary nebulæ, or "beards," that are not seen in the 40-inch. I do not know that these are verified by photographs. One is almost

1907MNRAS..67..543B

tempted to ask if this singular feature was not in some way a product of the great reflector itself—a want of exact definition. I offer this only as a possible explanation, which in itself seems to me to be very doubtful. Instances of this peculiarity are seen in the drawings of M 97, M 57, G.C. 450, G.C. 2098, G.C. 464, etc. But these appendages do not seem to be real.

A remarkable example of some of these peculiarities is the drawing of M 97—the celebrated "Owl" Nebula—made in 1848 with the great reflector. This picture for a half century was a classic among the drawings of nebulæ. And indeed it might well be, for it represented the nebula as a weird bewhiskered grinning face, with two dark spots where the eyes should be. In each of these dark spots or eyes a considerable star, which formed the pupil of the eye, was shown. The whole representation is strikingly like the face of an owl, or some uncanny cross-eyed goblin which only needs a pair of legs to execute some fiendish dance in space.

In recent years this fascinating picture seems to have dropped out of astronomical books, mainly, I believe, because when the nebula was examined in the sky with other powerful telescopes the two stars no longer formed the pupils of the eyes. In fact, there seemed after all to be only one star in the nebula; and this star, furthermore, was not in either of the eyes, but really occupied the bridge of the nose between the eyes!

Nevertheless, I believe that this drawing, shorn of some of its structural details and appendages, is important. There does not seem to be any question but that there were two stars in the nebula which were seen with the great telescope in 1848 and later. The main question is the true location of these two stars at that time with respect to the large dark spots in the nebula. If the drawing, which seems to be corroborated by the observer's notes, correctly represents the position of these two stars—both or either one—as being in the dark spots, then a change has occurred in the nebula, for the two stars are there and have not changed their places in the sky.

The brighter of these two stars occupies the centre of the nebula. In the observations of 1848 it is described as being in the centre. If this star is the nucleus of the nebula—and it probably is, though it is more star-like in appearance than are the nuclei of the nebulæ in general—then the nebula has not moved, for the star has not sensibly changed its place.

There is only one other means by which a displacement of the holes with respect to the two stars is possible, and that is a rotation of the nebula. Motion of translation or of rotation in the nebulæ is not improbable when time enough lapses to show it. We do not have, however, a single example where motion is proved, outside of spectroscopic results.

If this nebula were sensibly rotating from west to east, on an axis whose position angle is 50°, then the holes would have been further east on the disc in 1848; and if the velocity of rotation

1907MNRAS..67..543B

were great enough, the two stars would have occupied the position in the holes shown in the drawing of Lord Rosse. While I do not believe this is the true explanation of the discrepancy in the early drawings of this nebula, it will at least serve as a working hypothesis.

Following is a collection of notes which relate to the stars in the nebula. They are taken from the papers of Lord Rosse in the *Philosophical Transactions of the Royal Society* and the *Scientific Transactions of the Royal Dublin Society.*

From the *Transactions of the Royal Society*, 1850.

1848 March 11. Two stars considerably apart in the central region. Dark penumbra around each, spiral arrangement, with stars as apparent centres of attraction; stars sparkling in it, resolvable; night excellent. Note by Mr Rambaut.

1848 March 11. Remarkably fine night; a brilliant star in the centre; also star to the right; round each a black space (see sketch). Note by Mr Rambaut.

1848 March 26. Second bright star visible; spiral arrangement hardly perceptible; not seen so well as on the 11th of March.

1848 March 27. Not seen so well as last night; second star seen at rare intervals, power 468.

1848 March 28. Night hazy, could not see second star.

1848 March 31. Caught one glimpse of second star, but saw the large star very plainly.

1848 April 3. Small star distinctly seen.

1848 April 6. First star seen easily, though hazy; the second only occasionally.

1848 March 9. Second star only seen for a moment. Several attempts were made to procure measures of position and distance of the two stars this spring, but in vain, the season was so unfavourable. . . . With the micrometer as at present mounted there would not have been the slightest difficulty in procuring measures.

From the *Transactions of the Royal Dublin Society*, vol. ii. (New Series), Aug. 1879.

[See p. 7, 1850. Plate xxxvii. fig. 11.]

1848 March 11. Brilliant star in the centre. After 5^{m} observation detected the star to the right, which Dr Robinson immediately saw. Round each star seems a black space.

1848 March 26. Seen better than last night. 2nd star seen at frequent intervals with S star appearing now and then through the neb. part.

1848 March 27, 28, 31, April 1. Not well seen, 2nd star only seen at rare intervals.

1848 April 3. S star seen plainly enough.

1907MNRAS..67..543B

1850 March 9. S star barely visible for a moment. Uncertain measure of its pos. from central star 331°·5 (Lord R.).

Between 1850 March 15 and 1858 March 8, viewed 18 times. S star not seen, nor minute details.

1858 March 11. *v*F star once suspected almost p the central star, but very uncertain. 2nd star not seen.

1858 April 3. Suspected star (see last obs.) not verified. A very minute star s f the middle one, just on the outer edge of dark hole, was more strongly suspected.

1863 Feb. 12. One star plainly seen, and at moments I fancied I saw a star n f it and one in s f edge, but only by glimpses. I have the merest suspicion of one in n p edge.

1868 Feb. 15. Star in centre, one on cross-bar near n extremity, susp. comp. to central star. S star on s f edge of f hole and sev. others susp. at moments.

1868 Feb. 28. Comp. susp. p central star.

1872 March 12. Star n f from central star. Pos. 22°·9 (3). Dist. 157″·6 (3). No other star distinctly seen. power 414, possibly one or two e F st f the central one, on the edge of the hole.

1874 March 9. Minor Axis Pos. 41°·4 (2) Diam. 147″·4 (2).
Major Axis „ 126·2 (2) „ 163·5 (2).
Central star 14 mag., no other st steadily seen.

As will be seen, the notes in these observations are frequently rather vague. Sometimes it is impossible to tell just what is meant.

It seems quite clear, however, that the "second star" frequently referred to was really the one which I have measured and called 2. The note of 1848 March 26, where it is referred to as "second bright star," is not reconcilable with their later observations of it, nor with its appearance to-day, for in the later notes it seems to have been a difficult object.

The direction of the 2nd star given by Lord Rosse on 1850 March 9 of 331°·5 must be 180° in error to agree with the previous descriptions. If this is so, and I think there is no doubt that it is, then the position angle 151°·5 would agree as closely as could be expected with my observation of 153°.

On 1907 April 5 I gave an exposure of $6^{h}\ 0^{m}$ on the place of this nebula with the Bruce 10-inch doublet. The sky was fair for such work, but not specially good. Clouds at one time covered the region.

The general appearance of the nebula on this photograph is that of a round mass, with a bright central star and two unequal dark places, one on each side of this star. The following is a description of the object under a considerable magnifying power as it appears on this plate. There seems to be a slightly elliptical disc, with its axis very roughly in P.A. 160°, superposed unsymmetrically upon a fainter circular disc. The greatest displacement of these two discs is on the following side, where the edge of the brighter one is $\frac{2}{10}$ of radius nearer the central star. There is some detail in the south preceding portion of the nebula in the form of a narrow curved mass of greater

1907MNRAS..67..543B

brightness running toward the south side. There is also some detail of a similar nature near the north edge. The following hole is much smaller than the preceding one, its following edge is not quite $\frac{1}{2}$ radius from the nucleus. The preceding edge of the preceding hole extends over $\frac{7}{10}$ radius from the nucleus. The nucleus is so large that it almost obliterates the separation between the two holes, so that they appear nearly to merge into each other. There are suggestions of considerable detail on the nebula—especially in the north and south parts. The second star (2) is faintly visible just outside the south following edge of the following hole. There are no traces of fringes or other appendages to the nebula.

Among the many nebulæ photographed by the late Dr Roberts with his 20-inch reflector was M 97. A reproduction of his photograph is given in vol. ii. of Roberts' Celestial Photographs. Of this photograph which was made on 1895 April 20 with four hours' exposure, Dr Roberts says: "It (the nebula) measured about 203″ of arc in length, and the star referred to by Rosse is very conspicuously seen in the centre, its magnitude being about the 15th, but there is no other star anywhere in the nebula."

Dr Roberts' photograph is wrongly oriented in plate 19. South is above, and following is to the left. Below it, on the same plate, is a photograph of M 57 Lyrae, which is correctly oriented—south above, and preceding to the left. I call attention to this fact, otherwise it may cause confusion in comparing the picture of M 97 with observations. The photograph must be looked at in a mirror, which will correct the orientation. There is no faint star in the open sky outside the nebula on Roberts' plate that is not shown equally well or better on mine.

Following is a collection of my notes on the nebula as it appears with the 40-inch refractor.

1899 Feb. 6. The star (2) is just free of the dark opening. A sketch shows it outside the south following edge of the following hole.

Feb. 7. Small star difficult to measure.

1900 Dec. 18. The small star is not in the south following opening, but is just free of it, and is on the nebulosity south following. This star is rather hard to measure. Sketch.

Dec. 25. A sketch shows the small star just free of the following part of the hole. Very faint and difficult, and only seen by glimpses.

1902 Feb. 7. The central star is $16^{m}\cdot5$. It is very difficult. Can see the other star (2) faintly. The star measured (1) is between the two eyes on the bridge of the nose, but nearer the following hole.

1907 March 5. The edge of the nebula reaches just half way to the 10^{m} star north [star (4)].

March 10. Star 2 is $1\frac{1}{2}$ magnitude less than the central star. The following hole is the more distinct and darker of the two. The central star is nearer the following hole but not in it.

March 17. The central star would be 13^{m} if free from the

1907MNRAS..67..543B

nebulosity. Can feebly see the two other stars. The following one (2) is on the south following edge of the following hole. It seems to be either on the edge or within the nebulosity outside the hole. The other small star (3) is very difficult. The preceding hole is further from the centre than the following hole, and there is not much contrast with the nebulosity. That side of the nebula seems somewhat less bright and less distinct. Cannot make out any spiral arrangement. Tried pulling out the eyepiece, but this did not seem to make any improvement. The edges of the nebula, though rather definite, are very indistinct—especially the preceding edge. With a magnifying power of 700 diameters, the south following star (2) is very close to the following edge of the following hole, but outside of the hole. The central star is north following the line between the two holes, and is nearer the following hole. The following hole is the more distinct of the two and is nearer the middle.

April 2. Sky fairly clear. The following estimates of brightness were made. Central star (1) = $13\frac{1}{2}^{\mathrm{m}}$ or 14^{m}. Star (2) = 15^{m}. Star (3) is 1 magnitude less bright than (2). Tried drawing out eyepiece, but could not see any more details. There does not seem to be any structure, spiral or otherwise. The nebula is irregularly round—the edges very ill-defined.

I have the following observation of this object with the 36-inch, 1894 April 8, with a magnifying power of 350. There is a rough sketch of the central star and the two holes :—

"The nebula is round. The edges fairly well terminated. There is a 15^{m} star [the central star] just free of the preceding edge of the following dark hole ; there are one or two faint stars south following this hole, but no star in either hole. The following hole is the more noticeable. I do not see any spiral structure. The [central] star is on the following side of the bridge, but not in the hole."

I suppose the "one or two faint stars south following the hole" were stars (2) and (3). The description of the position of the central star on the bridge between the two dark holes would rather show there has been no decided change in the holes in the past ten or fifteen years.

I think the central star is variable. It has sometimes appeared much fainter than at others. Of course it is very difficult to decide on the variability of a faint star involved in nebulosity, for conditions of seeing, etc. affect it far more than when the star is in the open sky. On 1902 Feb. 7 it was estimated to be $16\frac{1}{2}$ magnitude, and was very difficult. I would not consider this alone as of any importance were it not that a note says that star (2) was visible. This would imply that there could be but little difference in their brightness at that time. It will be watched further for change.

Below are given my measures of the stars in this nebula. The diagram on Plate 3 shows the relative places of these stars with reference to the two dark spots.

1907MNRAS..67..543B

Measures of Stars in Messier 97.

Nucleus (1) and (4).

	°	″	m	m	
1899 Feb. 6	24·85	157·52	14	10	
7	.....	158·58			Single distances.
	24·85	158·05			
1900 Dec. 18	24·86	158·28	13	10	
25	24·92	157·90		10·5	
28	24·70	157·99	14	10·5	
	24·83	158·06			
1902 Feb. 7	24·80	157·69	16·5	10	
8	24·97	158·26			
24	24·98	158·68			
	24·92	157·88*			
1907 Feb. 10	24·72	158·06			
Mar. 5	24·94	158·01			
	24·83	158·03			

Nucleus (1) and (5).

	°	″	m
1900 Dec. 25	184·77	180·87	12
28	184·88	181·20	12
1901 Jan. 20	184·91	181·13	11·5
	184·85	181·11*	

Nucleus (1) and (2).

	°	″	m
1900 Dec. 25	152·89	40·76	16
1907 Mar. 10	153·99	40·78	16
	153·44	40·77	

Nucleus (1) and (3).

	°	″	m	
1907 Mar. 5	205·1	36·8	16	Single distances.

In volume ii., Publications of the Lick Observatory, Professor Burnham gives three measures of the central star and the 10 magnitude star north. The mean is :

	°	″	m	m
1891·24	24·8	156·48	14·2	10·5

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* At the moment of going to press it was noticed that these means are not consistent with the figures above. The necessary rectification will be made in the next Number.

1907MNRAS..67..543B

He does not mention any other stars in the nebula.

From the visual observations in March of the present year, the following facts were determined:—

Diameter of the following hole = 34″·0 (1).

Diameter of the nebula in the direction of 25° = 155″·4 (1).

Distance from following edge of following hole along the axis of the two holes to following edge of nebula = 43″·4 (1). Position angle of the line between the centres of the two holes = 134°·2 (2). This line would pass 5″ or 10″ south preceding the central star.

To decide whether the "central star" was really central in the nebula, the distances from the star to the edges of the nebula in four directions were measured:—

P.A.	°	″	
	28	81·0	(2)
	118	81·6	(3)
	208	80·3	(2)
	298	80·0	(4)

It was difficult to set on the edges of the nebula, especially in the direction 28°. In that direction another night's measures gave 71″·2 (2), but the seeing was very bad, and the photograph shows that the fainter outline here was perhaps not seen, and that the measures doubtless refer to the edge of the brighter disc. I have rejected that set. The central star would therefore appear to be in the centre at least of the fainter disc. A mean of all the measures would make the diameter about 160″. The numbers in parenthesis indicate the number of settings of the wires.

A copy of my drawing of M 97 is given in Plate 3. It is a fair representation of the nebula as it appears in the 40-inch telescope. For comparison, I have mounted beside it a copy of the Rosse drawing, which I have assumed is correctly oriented in the *Philosophical Transactions* for 1850, south above, preceding to left. I have, however, tilted it so that the line between the eyes is parallel to that in my drawing. The Rosse picture is more interesting when turned upside down.

Yerkes Observatory :
1907 *May* 16.

1907MNRAS..67..543B

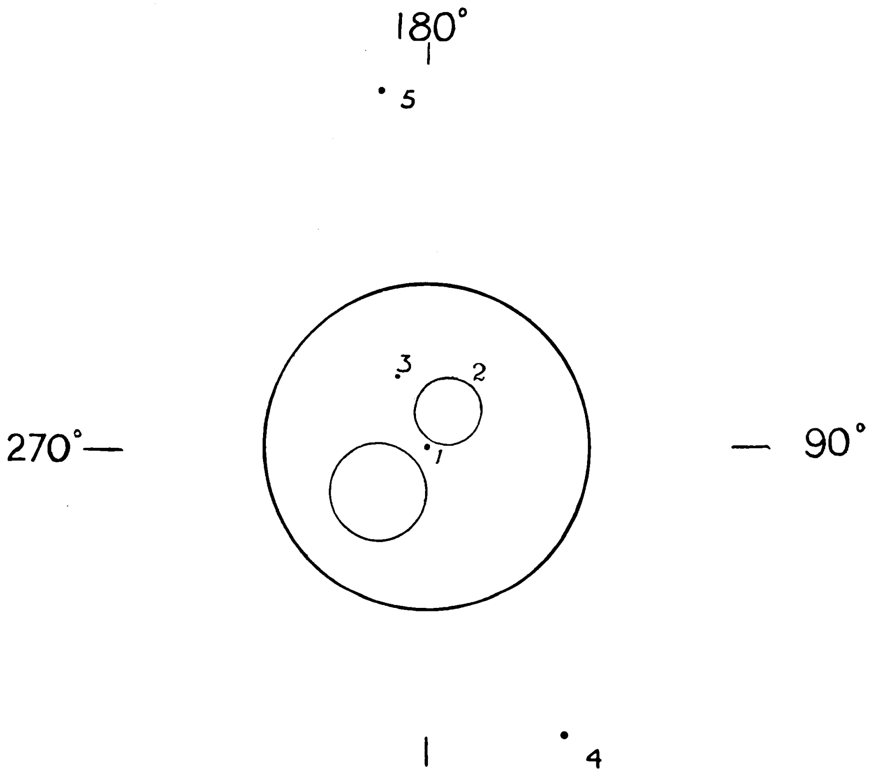
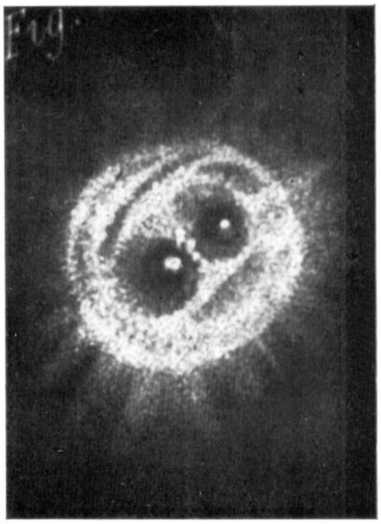
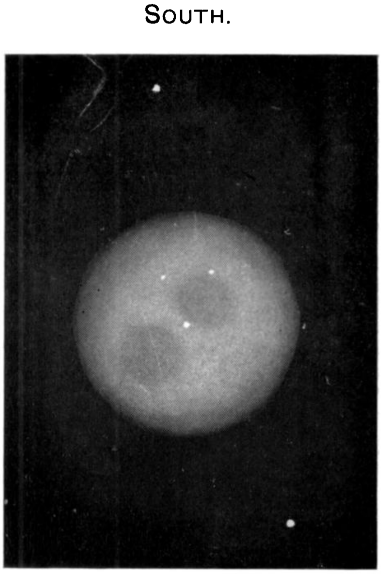


DIAGRAM OF THE "OWL" NEBULA FROM THE MEASURES.



THE "OWL" NEBULA WITH LORD ROSSE'S GREAT REFLECTOR IN MARCH OF 1848.



THE "OWL" NEBULA WITH THE 40-IN. REFRACTOR OF THE YERKES OBSERVATORY IN MARCH 1907